3-D magnetotelluric inversion with coast effect modeling to assess the geothermal potential of Anses d'Arlet (Martinique, Lesser Antilles)

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SUMMARY

Within the framework of a global French program towards development of renewable energies, Martinique Island (Lesser Antilles, France) has been extensively investigated (from 2012 to 2013) through an integrated multi-disciplinary approach, with the aim to identify precisely the potential geothermal resources previously highlighted (Gadalia et al., 2014). Among the investigation methods deployed (geological, geochemical and hydrogeological), we carried out three magnetotelluric (MT) surveys at three of the four most promising areas of Martinique, namely the Anses d'Arlet, the Montagne Pelée and the Pitons du Carbet prospects. A total of 32 MT tensors were collected in the Anses d'Arlet area in the frequency range 1000 Hz to 10^{-2}-10^{-3} Hz together with TEM soundings for potential static shift correction. A 3-D MT inversion of the full tensor was carried out including the coast effect.

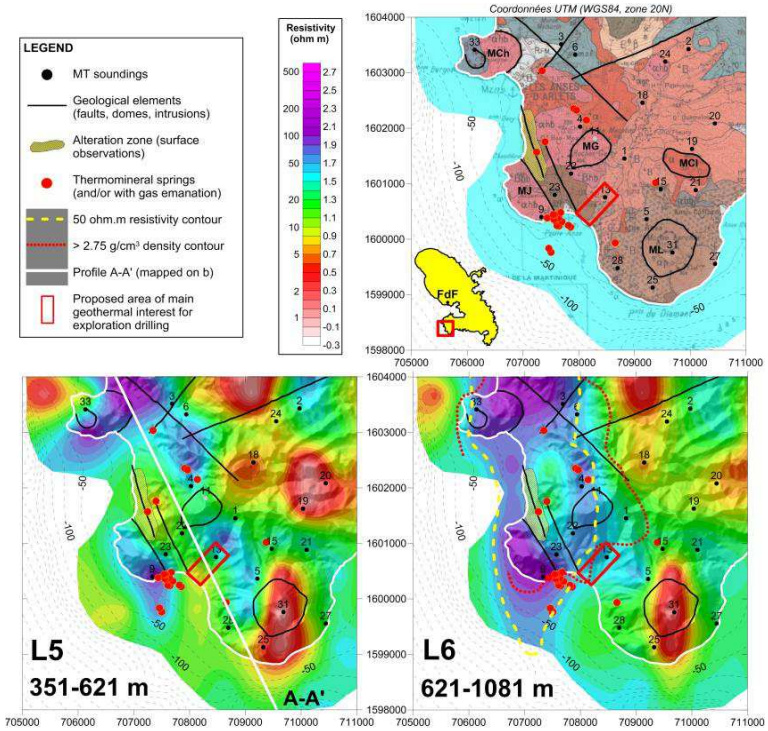

Figure 1. Location map of the investigated area on geological background. (Westercamp et al. 1990) and resistivity models from 351 to 1081 m deep (b, c, d, e). Superimposed elements are indicated in the legend.

The 3-D resistivity model reveals a major resistive body elongated in the NNO-SSE direction, corresponding to the main structural volcanic axis of the area, and interpreted as a deep intrusion almost reaching the surface. Based on geological observations – an alteration zone located between Anses d'Arlet and Petite Anse – the shallow conductive layer identified eastward is interpreted as the remaining of an old cap-rock partly eroded that becomes thicker southwards. The latter could be related with the altered core of the Morne Larcher. Other studies allowed the reconstructing of the geothermal system evolution to its present and moderate apparent activity mainly located south of the resistive anomaly. This intrusion could act as heat source for the geothermal system. This sector is identified as the most interesting for further exploration wells.

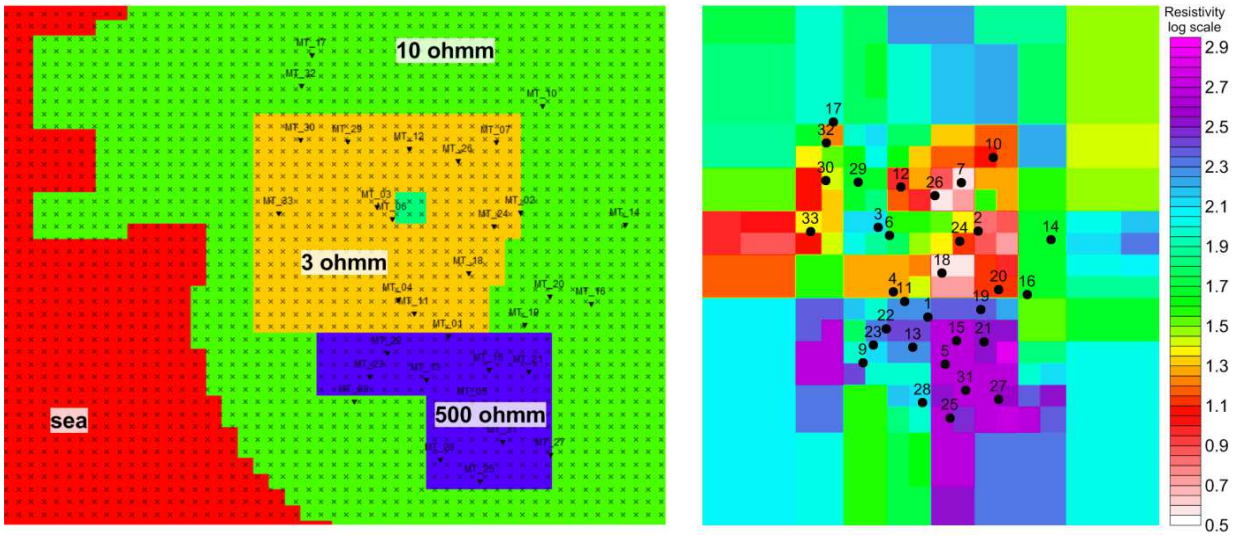

Figure 2. Left: synthetic model of the Anses d'Arlet province with arbitrary 3-D resistivity structure at 350-480 m depth. 32 MT soundings for which response is computed. Resistivity distribution is indicated. Right: inversion results at layer 5 (depth: 270 to 460 m). Be careful, scale is not equivalent on both plots.

In order to better understand structures highlighted by the real data distribution and test the strategy to integrate correction coefficients for the coast effect (modeled separately) during the inversion, we designed a forward model using the same bathymetry, topography and MT sounding distribution of the survey. Impedance tensors were calculated for the 32 sites. The geometry of the 3-D structure has been designed quasi-independently of the data distribution to assess the impact of un-appropriate acquisition grid. The 3-D inversion was run with these synthetic data (Hautot et al, 2000, 2007). The results indicate that the general structure is recovered for the first 1000 m. Deeper, and southward, the absence of MT soundings surrounding the resistive body prevented a good lateral constraint, causing its disappearance. To the north, the conductive body "pseudo caprock" is well defined, especially on layer 5 (Figure 2), were the apex of a supposed geothermal reservoir could be identified (sites 3 and 6). Deeper the eastern border remains very well constrained by the eastern MT synthetic soundings.

Keywords: Magnetotelluric, 3-D inversion, Anses d'Arlet, Martinique, Geothermal exploration

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